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EVALUATION OF PAPERCRETE: An Innovative Building Material

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Abstract-**The major component in any construction activity is cost of the materials. In developing countries, the untapped or unused resources are needed to be identified for its potential usage in the construction sectors. The one such resource is waste papers. In this research paper, waste papers and recycled paper mass are incorporated into concrete at various percentages to increase the bulk of the concrete, and all the necessary engineering and physical properties are studied and mathematical equations are derived and compared with control concrete. The potential usages of this new material are discussed in detail.**

***Index terms* – Paper Sludge, Tensile Softening, Compressive Strength, Split Tensile.**

I. INTRODUCTION

Shelter is the most compelling element of any life style. In developing countries like India, millions people are homeless and affordability for the construction of house inremote. This is because of cost of building materials which itself 2/3 of total estimated cost of any building. The cost of building materials are being escalated indefinitely. In such a situation and for country like India, utilization of the waste products in the construction industry is highly essential. Nevertheless a number of papers published on the subject of utilizing waste products in the building industry with growing interest by developing and developed countries, research institutes and universities [1].

Paper concrete (papercrete) is one of such important building materials and remarkably inexpensive since all its constituent materials (except hydraulic cement) are free or nearly free.

Undoubtedly, this innovative building material will soon catch its potential to revolutionize the industry. Papercrete will offer a way to turn "trash" paper and cardboard into inexpensive houses that be strong, well- insulated and easily built. It is certain that the papercrete can provide affordable housing for millions of people who are homeless or inadequately housed.

In this research work, the papercrete is made out of hydraulic cement i.e., ordinary Portland cement (OPC), sand, Coarse aggregate and well ground wet paper mass after milling is added at various percentages by the weight of OPC into the normal concrete. Paper and cardboards are principally wood cellulose which is considered to be a fibrous material. It should be noted that the cellulose is the second most abundant material available on earth after rock. Paper cellulose is a natural polymer, a long chain of linked sugar molecules. The links in the cellulose chain are a type of sugar ß – D glucose. The cellulose chain bristles with polar –OH groups. These group forms many hydrogen bonds with –OH groups on adjacent chains, bundling forms the basis of papercrete's strength.

Sand and coarse aggregate are added to the mix to increase compressive strength and insulating value. Each and every individual sand grain is embedded in the matrix and the cement is surrounded by insulating air pockets and paper fibers. Because of all that insulation, it takes relatively long time for heat to flow from one grain to another. Since sand is distributed evenly throughout the mix, it is ultimately end up with the ultimate thermal "flywheel effect" which is amazing efficient.

II. EXPERIMENTAL PROGRAM

A. Materials used

Ordinary Portland cement (OPC) 43 grade of Dalmia brand conforming to IS 8112 was used. The river sand sieved through 600 micron with a fineness modulus of 2.00 was used as fine aggregate. The coarse aggregate used was 10mm and down size, the specific gravity was 2.6.waste papers collected from various sources comprising of old newspapers, cardboard boxes and other waste paper packing materials were made or cut into small pieces and soaked in water for three days and then subjected to grinding in wet grinder. After it has been ground to required fineness and consistency the paper mass was collected from the wet grinder and stored for casting of paper concrete specimens. The Fig. 1 shows the tarned paper pieces and soaked in water, Fig. 2 shows the grinding process of the soaked paper, the Fig. 3 shows the paper mass after grinding in the wet grinder. The water used for mixing the papercrete was ordinary portable tap water.

Fig. 1 Paper pieces soaked in water

Fig. 2 Grinding of soaked papers

Fig. 3 Paper mass ready to make papercrete

B. Mix proportions and casting of specimens

The Table 1 shows the mixture proportions used for this study. One control mix 1:1.5:2 with w/c ratio of 0.4 was adopted, and seven paper concretes were experimented with the addition of paper mass at 2.5% to 35% by the weight of OPC.

Table 1 Mix Proportions of Papercrete

Mix ID	OPC	Sand	Coarse aggregate	% of Paper Mass by weight of OPC	w/c (%)
C	1.00	1.5	2.00	-	0.40
P1	1.00	1.5	2.00	2.5	0.40
P2	1.00	1.5	2.00	5	0.40
P3	1.00	1.5	2.00	10	0.40
P4	1.00	1.5	2.00	15	0.45
P5	1.00	1.5	2.00	20	0.45
P6	1.00	1.5	2.00	30	0.45
P7	1.00	1.5	2.00	35	0.50

For cube compressive strength test 150mm x 150mm x 150mm size cubes were cast, for cylinder compressive strength test 80mm diameter and 150mm long cylinders were cast , for the determination of dry and saturated densities 80mm diameter and 50mm thick disk specimens were prepared. For the determination of split tensile strength tests 80mm diameter and 250mm long cylinders were used. The flexural strength was obtained from the beam specimen of size 50mm x 50mm x 300mm. For shear strength determination, small cylinders of size 50mm diameter and 100mm long specimens were cast. For finding the efficiency of the coating systems on water absorption, square tile specimens of size 100mm x 100mm x 25mm were cast. For arriving impact resistance of this new material tile of size 250mm x 300mm x 10mm thick were used.

C .Experiments/ Testing

Table 2 gives all the mechanical strength characteristics of paper concrete such as cube compressive strength, cylinder compressive strength, split tensile strength and flexural tensile strength of various papercrete mixtures after 28 days of curing in separate curing tank. Fig. 4 shows the experimental result of cube compressive strength and Fig. 5 shows the experimental result of cylinder compressive strength test results. Fig 6 shows the failure modes of cubes and cylinder under compression. The failure type is type 3 as per ASTM C 39/C39M-09a which is known as columnar vertical cracking through both ends, no well formed cores. Fig. 7 shows the result of splitting tensile strength. Fig 8 shows the trend of variation of flexural strength of papercrete. Table 3 and Fig. 9 shows the result of impact test carried out on tile specimens of 250mm x 300mm x 10mm. the physical parameters such as dry density, saturated density, percentage of water absorption and the coefficient of water absorption etc are presented in Table 4.

Table 2 Mechanical strength parameters of paper concrete

Mix ID	% of Paper mass	Cube compressive strength (f_{cu}) MPa	Cylinder compressive strength (f_{cy}) MPa	Splitting tensile strength (f_{sp}) MPa	Flexural tensile strength (f_r) MPa
C	-	63.01	34.08	2.89	6.81
P1	2.5	56.62	36.50	3.17	4.36
P2	5.0	54.56	19.56	3.07	6.49
P3	10.0	48.26	16.97	2.86	7.97
P4	15.0	30.49	13.25	2.23	8.75
P5	20.0	27.00	9.54	1.51	9.13
P6	30.0	19.09	7.63	1.37	10.12
P7	35.0	16.49	5.87	0.79	10.84

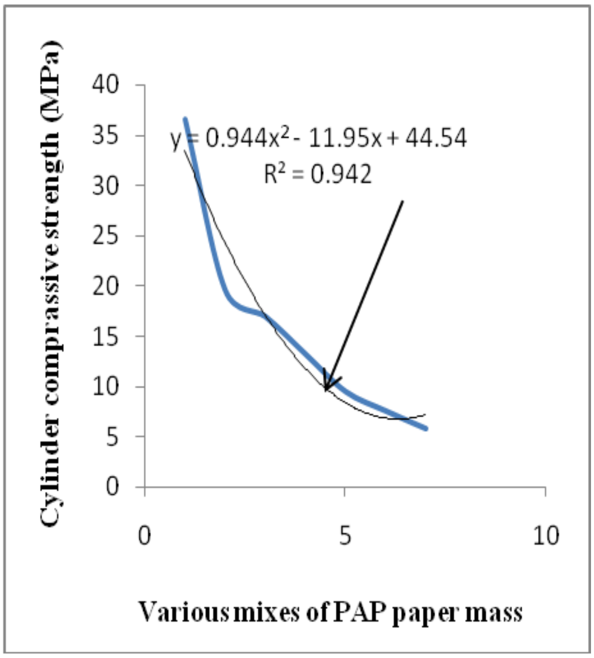

Fig. 5 Cylinder compressive strength of papercrete after 28 days

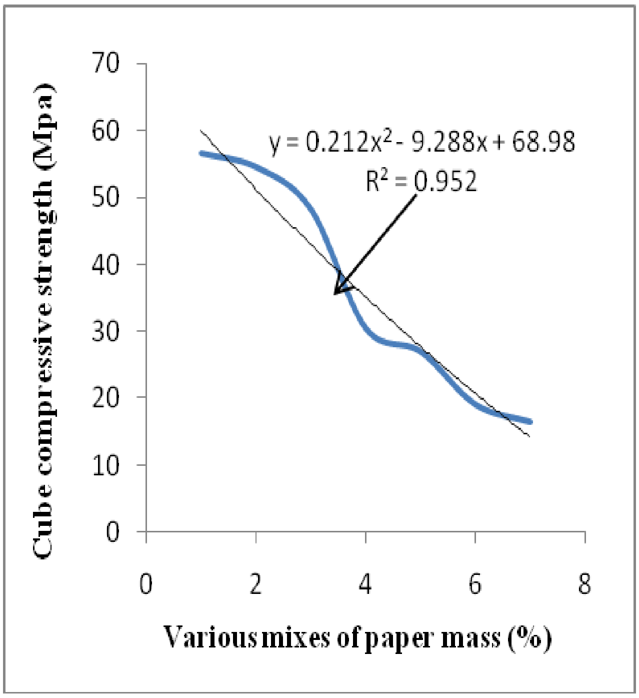

Fig. 4 Cube compressive strength of papercrete after 28 days

Fig. 6 Failed specimen after compression test

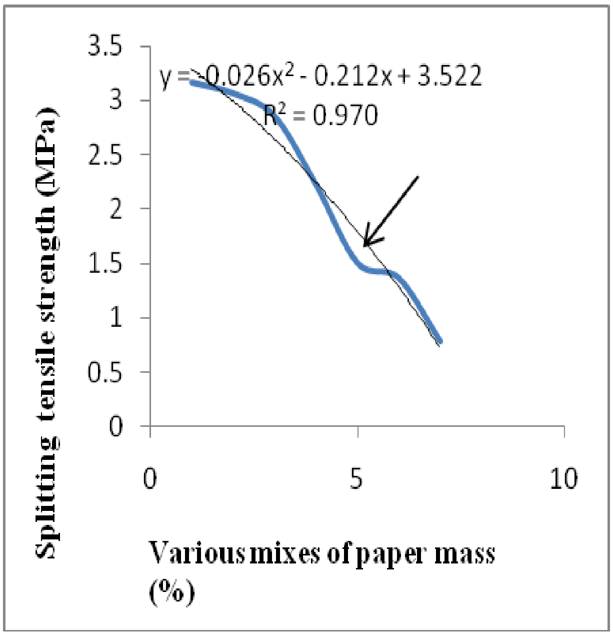

Fig. 7 Splitting tensile Strength of papercrete after 28 days

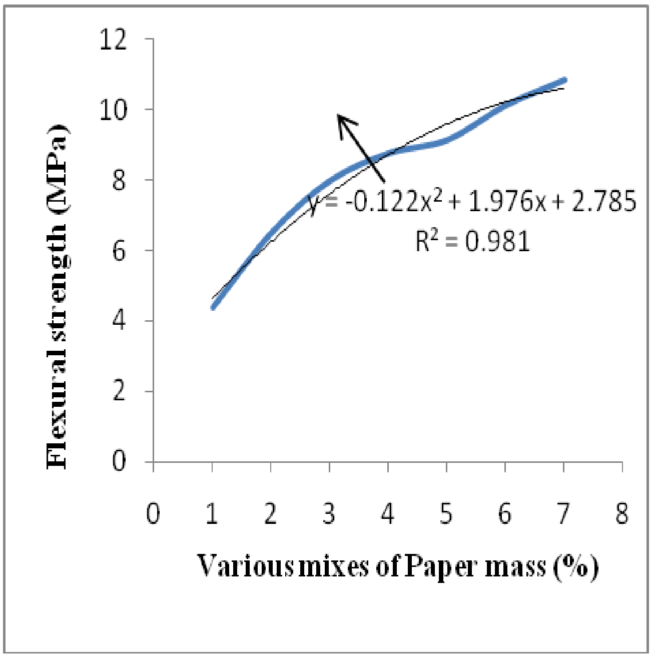

Fig.8 Flexural Strength of Papercrete after 28 days

Table 3 Impact Resistance Strength of Papercrete after 28 days curing

Mix ID	Weight of Steel ball (gm)	Height (mm)	Energy Absorbed (kNmm)
C	560	200	1.12
P1	560	300	1.68
P2	560	350	1.85
P3	560	380	2.13
P4	560	430	2.4
P5	560	470	2.63
P6	560	530	2.96
P7	560	580	3.25

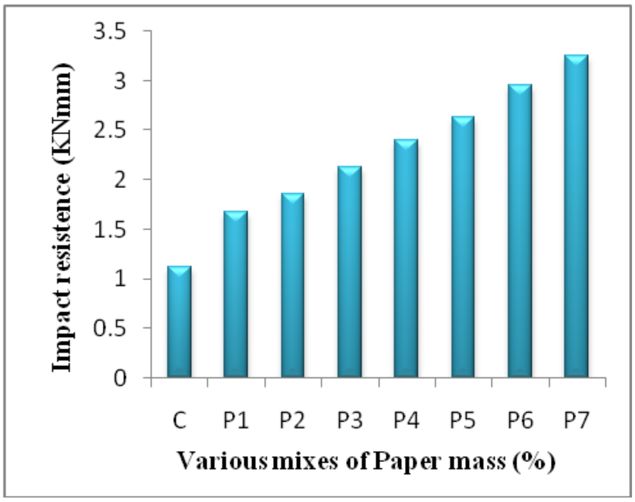

Fig. 9 Impact Strength of Papercrete

Table 4 Micro structural Properties of Papercrete

Mix ID	% of Paper mass	Dry Density (Kg/m^3)	Saturated density (Kg/m^3)	Water Absorption (%)	Coefficient of Water Absorption Ka x 10^{-10} (m^2/s)
C	-	2396	2460	2.67	0.98
P1	2.5	2240	2564	14.46	1.18
P2	5	2180	2596	19.08	1.35
P3	10	2080	2640	26.92	1.65
P4	15	2000	2704	35.20	2.0
P5	20	1920	2720	41.67	2.63
P6	30	1880	2728	45.10	2.88
P7	35	1840	2760	50	3.83

III. RESULTS AND DISCUSSION

The Table 1 presents the percentages of paper mass additions into conventional concrete. As the percentage of the paper mass increases, the demand of water for mixing also increases. This is due to absorption characteristics of cellulose materials in water. Table 2 shows all engineering characteristics strength values of papercrete. The trend of cube compressive strength is in descending order and which could be seen from Fig 4. As the paper mass content increases, the strength falls down. The same trend was observed in Fig 5 for cylinder compressive test. This is due to loss in cohesion and also the binding of calcium- hydrate – silicate (C-S-H) gel on cellulosic material is very poor. The splitting tensile strength shows mixed response up to 5% addition of paper mass the tensile strength against splitting is increased compared to control mix. For 10% paper mass addition, the strength against split in almost equal to control concrete and any further addition of paper mass in concrete had lead to reduction of split strength. It is observed that while applying load for split tensile test, a considerable amount of deformation of material has taken place which can be seen from Fig. 10.In contrast to split tensile test, the flexural tensile test carried out by beam specimen shows increasing values as the percentage of paper mass is increased, except for 2.5% and 5% addition of paper mass. This can be attributed to the fact that this cellulose fibre bends sufficiently to receive the bending stresses produced during the flexural tests. This indicates this application for structural beams, boards, partitions and roofing sheets. Table 3 and Fig. 9 shows that the impact resistance is increased as the percentage of paper mass is increased. The fibrous cellulosic material absorb high

amount of impact forces. The Fig. 11 shows the result of impact test on tiles before and after. Multiple fracture or cracks did not occur because of fibrous effect and absorption of energy by the mixture in the papercrete. This again proves that this material is quite suitable for wall partitions and roofing sheets. The Table 4 shows the water absorption characteristics of the papercrete. As the paper mass content is increased, the percentage of water absorption was also increased drastically. Therefore this result indicates the necessity of water proofing of the material or coating on the material is highly essential. High amount of water absorption is due to the presence of cellulose materials that easily absorbs water and retains it for long time.

Fig. 10 Deformation of specimen under split test

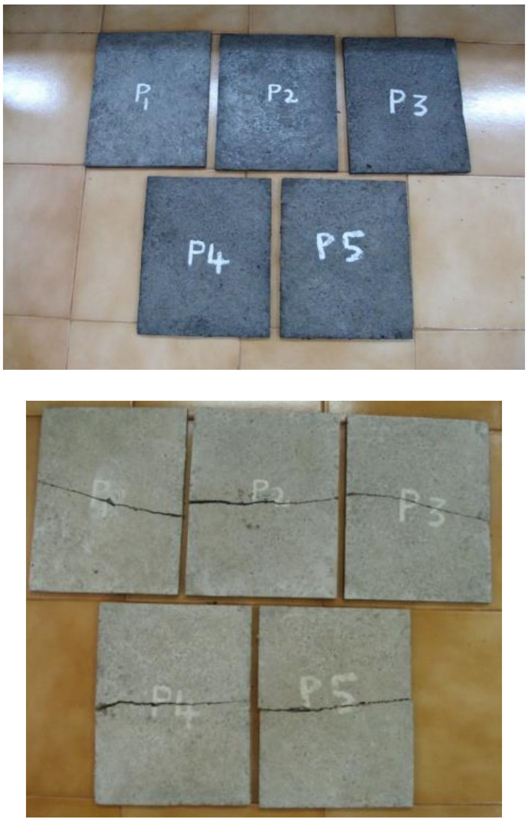

Fig.11: Impact test on tile specimen(Before and After)

IV. CONCLUSIONS

1) As the percentage of paper mass is increased, the cube compressive and cylinder compressive strength are decreased drastically.
2) Mixed response was found in case of split tensile test. Up to 5% addition of paper mass, the split tensile strength has improved and beyond this percentage the strength is reduced gradually.
3) In flexural beam test, the flexural strength has increased drastically after 5% addition of paper mass. This behavior in tension is completely against split tensile test. Therefore this material quite fit to make pavement tiles, partitions boards, ceiling boards and other lightweight components of structures.
4) As the paper mass content is increased, the impact resistance also increased.
5) Increase in paper mass in concrete, increases water absorption drastically and therefore either integral water proofer or water proof coating on this material is inevitable.

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